Strength in numbers: Physicists identify new quantum state allowing three -- but not two -- atoms to stick together

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(Phys.org) -- A Kansas State University-led quantum mechanics study has discovered a new bound state in atoms that may help scientists better understand matter and its composition.

The yet-unnamed bound state, which the physicists simply refer to as "our state" in their study, applies to three identical atoms loosely bound together -- a behavior called three-body bound states in quantum mechanics. In this state, three atoms can stick together in a group but two cannot. Additionally, in some cases, the three atoms can stick together even when any two are trying to repel each other and break the connection.

"It's really counterintuitive because not only is the pair interaction too weak to bind two atoms together, it's also actively trying to push the atoms apart, which is clearly not the goal when you want things to stick together," said Brett Esry, university distinguished professor of physics at Kansas State University and the study's lead investigator.

Esry, along with Kansas State University postdoctoral researcher Nicolais Guevara and University of Colorado-Boulder colleague Yujun Wang -- a Kansas State University graduate -- calculated the quantum state in their study, "New Class of Three-Body States," which was recently published in Physical Review Letters.

The state is similar to Efimov three-body states, a loosely-bound quantum state first predicted by Russian physicist Vitaly Efimov in the early 1970s. Physicists were able to first observe Efimov three-body states more than 30 years later through an experiment with ultracold atomic gases in 2006. These gases are one-billionth of a degree kelvin above absolute zero -- a temperature that only exists in a handful of laboratories in the world. Esry said similar ultracold atomic gases are needed to observe their new quantum state as well since it can only exist at this temperature.

While Efimov three-body states only occur in ultracold conditions with atoms classified as bosons, the state found by Esry and colleagues applies to both bosons and fermions -- the two particle types that all matter can be classified as.

Additionally, the new quantum state exists in a pocket between short-ranged and long-ranged interactions. Short- and long-ranged interactions -- or forces -- are the distance at which the particle interactions are effective. With a long-ranged force, the particles have a greater distance between them and do not have to touch to interact and influence each other. With a short-ranged force, however, the particles must be in much closer proximity and interact similar to billiard balls colliding with one another, Esry said. The Efimov three-body states only exist for short-ranged interactions.

"The three-body states that we found are formed by interactions that are neither short- nor long-ranged," Esry said. "Instead, they lie right at the border between the two. So, more than anything, finding this new quantum state fills in a knowledge gap about three-body systems and quantum mechanics, which have been studied for centuries by physicists -- including Sir Isaac Newton studying the Earth, moon and sun."

Scientists may also find uses for the quantum state in experiments with ultracold atomic gases.

"That's really the nature of basic research," Esry said. "We're trying things that hopefully will pay off for somebody 20 years or longer down the line. Efimov had to wait 35 years to see his states actually be seen and used as a way to understand these three-body systems. We hope we don't have to wait that long."

Esry and colleagues will continue exploring this quantum state and to uncover how combinations of bosons and fermions behave in it.

Provided by Kansas State University

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